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(54) Title: CROSSLINKABLE POLYSACCHARIDES, POLYCATIONS AND LIPIDS USEFUL FOR ENCAPSULATION AND DRUG RELEASE

(57) Abstract

The present invention relates to a new form of biocompatible materials (e.g., lipids, polycations, polysaccharides) which are capable of undergoing free radical polymerization, e.g., by using certain sources of light; methods of modifying certain synthetic and naturally occurring biocompatible materials to make polymerizable microcapsules containing biological material coated with said polymerizable materials, composites of said polymerizable materials, methods of making microcapsules and encapsulating biological materials therein, and apparatus for making microcapsules containing biological cells (particularly islets of Langerhans) coated with polymerizable alginate or with a composite thereof (e.g., alginate and PEG). The present invention also relates to drug delivery systems relating to the foregoing, as well as bioadhesives and wound dressings made utilizing the foregoing technology.

wherein A is a polysaccharide, polycation, or lipid; X is a moiety containing a carbon-carbon double bond or triple bond capable of free radical polymerization (as described above), A and X are linked covalently as described above, Y is selected from alkylene glycols, polyalkylene glycols, or hydrophobic onium cations (e.g., tributylammonium iodide, tetrabutylammonium iodide, tetrabutylphosphonium iodide, and the like), and A and Y are linked through any one of the above described covalent linkages. In addition, where Y is an onium cation, A and Y can be linked through the following ionic bond:

$$-\overset{\overset{\displaystyle O}{\|}}{C}-O^{-}\ QR_4^{+};$$

wherein Q is nitrogen or phosphorus, and R is hydrogen, an alkyl radical, an aryl radical, an alkaryl radical, or an aralkyl radical.

The process of synthesizing the polymerizable biocompatible material comprises chemically modifying biocompatible material selected from a lipid, polycation or polysaccharide having a reactive functionality thereon, and then contacting the resulting modified biocompatible material with a free radical initiating system under free radical producing conditions. Reactive functionalities contemplated include hydroxyl, carboxyl, primary or secondary amine, aldehyde, ketone or ester groups. These groups are required in order to introduce at these sites, the appropriate polymerizable substituent.

Examples of biocompatible materials include polysaccharides such as alginate, high M-content alginates, polymannuronic acid, polymannuronates, hyaluronic acid, chitosan, chitin, cellulose, starch, glycogen, guar gum, locust bean gum, dextran, levan, inulin, cyclodextran, agarose, xanthan gum, carageenan, heparin, pectin, gellan gum, scleroglucan, and the like; polycations such as

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polyamino acids [e.g., polyhistidine, polylysine, polyornithine, polyarginine, polyalanine-polylysine, poly(histidine, glutamic acid)-polyalanine-polylysine, poly(phenylalanine, glutamic acid)-polyalanine-polylysine, poly(tyrosine, glutamic acid)-polyalanine-polylysine, collagen, gelatin, and the like]; random copolymers of: arginine with tryptophan, tyrosine, or serine; glutamic acid with lysine; glutamic acid with lysine, ornithine, or mixtures thereof; and the like; polymers containing primary amine groups, secondary amine groups, tertiary amine groups or pyridinyl nitrogen(s), such as polyethyleneimine, polyallylamine, polyetheramine, polyvinylpyridine, and the like; and lipids such as phosphatidylethanolamine, phosphatidylserine, phosphatidylinositol, phosphatidylglycerol, dilaurylphosphatidic acid, dipalmitoyl phosphatidyl glycerol, and the like.

A primary requirement of the polymerizable substituent is the presence of moieties containing carbon-carbon double bonds (C=C) which are polymerizable with free radicals generated by suitable initiator(s) e.g., an initiator system useful for UV and visible light polymerization. Examples of moieties containing such carbon-carbon double bonds are alkenoic acids (such as acrylic acid, methacrylic acid, and the like), as well as their corresponding acid chlorides (such as acryloyl chloride, methacryloyl chloride, and the like) and corresponding acid anhydrides (such as acrylic anhydride, methacrylic anhydride, and the like), alkenols (such as allyl alcohol, and the like), alkenyl halides (such as allyl chloride, and the like), organometallic alkenyl compounds (such as vinyl magnesium bromide), and the like.

A variety of free radical initiators, as can readily be identified by those of skill in the art, can be employed in the practice of the present invention. Thus, photoinitiators, thermal initiators, and the like, can be